Monitoring Walking Devices For Calorie Balance In Patients With Medical Rehabilitation Needs

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***Abstract*—This article presents a measurement system intended to monitor human footsteps. The goal is to guide the user's medical rehabilitation incorrect use to prevent dangerous situations and maximize comfort. Indicators of risk in question: the imbalance of movement in motor coordination and the number of calories to be burned for medical rehabilitation patients by balancing the patient's needs. Measurements are made by placing the sensor on one of the patient's legs. The main sensor accelerometer used in this study. The measurement system comes with an application link that allows patients and therapists to monitor the activity. Calibration and experimental results are presented in this article**

Keywords*— *Walking Devices, Calorie Balance, Medical Rehabilitation

I. Introduction

As the development of science and technology grows, more and more innovations emerge in various sciences. The development also raises the human awareness of the importance of medical rehabilitation especially for patients and parents who need medical rehabilitation. Movements can increase the risk of increasing accidents [1]–[7], especially when walking. The need for medical rehabilitation to perform movements, especially to burn calories into special needs, especially the movement of patients or parents cannot be done in vain.

Walking is a series of straightforward moves. Whatever speed and distance traveled, standing still is the key [8]. Walking is not just anyone can do, walking is also the most comfortable exercise because it is a daily activity. Walking alone has many benefits, and one of them is to lose weight in medical rehabilitation. To lose weight, it needs calorie burning.

Several solutions have been undertaken to address foot step monitoring problems [9]–[12], but the solution of the problem is too expensive to apply in everyday activities and is primarily still theoretical. Some solutions use an accelerometer and Inertial Motion Units (IMU) to obtain kinematic parameters on the movement of human footsteps [13]–[15]. The need in burning calories especially for medical rehabilitation patients and parents is a simple tool that is enough to calculate how many footsteps you have done and how many calories you have burned.

Quoted from the Healthy Food Star, a benchmark to calculate the burning of calories using distance. In taking 1.6 kilometers distance when walking, there are 100 calories burned. The distance is usually taken with 2000 steps. To get 1 pound or 0.45 kilograms of burning, counted must destroy 3500 calories. If you want to lose 1 pound per week, then you have to spend 500 calories per day [16].

Unlike the Healthy Food Star, according [16] to calculate the burning calories the benchmark used is the speed because although the distance traveled the same the speed is different, it can produce different calorie burning. Speed itself is obtained from the calculation of the number of footsteps divided by time (minutes).

Our paper is novel in that we apply accelerometer and gyroscope for calories calculation. In a study conducted using accelerometer and gyroscope sensors contained in the MPU6050 module, the sensor activity is then processed using the Mini Wemos D1 module with a supply of batteries that can last up to one day for continuous activity. The data from Wemos is then processed inside the user's Mobile to find out how many footsteps and calories are burned in one activity.

II. Method

A. The Human Cycle Walks

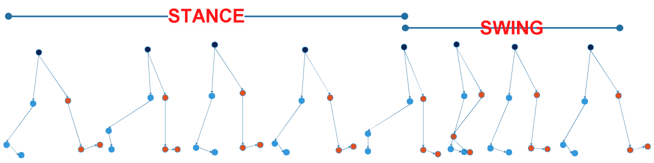

Fig. 1. The Human Cycle Walks

Viewed from the way humans walk shows that the pattern of movement of the human foot during the run has repeated cycles, so by analyzing these patterns detection steps can be done as shown Figure 1. The human pattern of stepping is basically two phases, phase stance and swing phase [2]. Phase stance is a state where one foot treads on the ground. The swing phase is the state in which one leg is raised. By the time one of the legs is in the stance phase, the other foot will be in the swing phase.

B. Sensor Placement

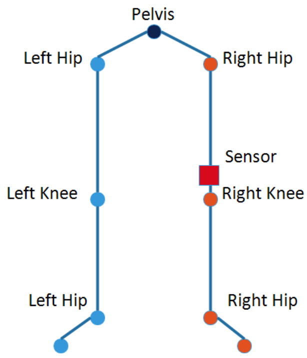

Fig. 2. Sensor Placement

In previous studies several studies have been conducted to find out where to place sensors effectively [17]. Sensor placement depends on the need, the research conducted by the sensor is placed on the right knee. When starting, a calibration process needs to be carried out, where calibration is used to get stable results from foot movements. When calibrating the leg is lifted to form a 90-degree angle with the other leg, then proceed with a relaxed walk. Algorithm 1 as calibration process need raw parameter from gyroscope and accelerometer.

C. Distance Legs

Humans on foot form a triangle pattern as shown in Figure 3. Before measuring the distance, it should be known how much the average width between the right foot and left foot when stepping. The United States customary units declare that the standardized unit of each human step is naturally calculated from the tip of the foot that is in front of the end of the previous leg.

$$step = distance * 0.78 \quad (1)$$

The average step is 78cm or assumed to be a human step along the 0.78m [3]. If it is known the width multiplied by the number of steps that we do then the distance traveled when walking with the formula as Equation (1) The Human Cycle Walks.

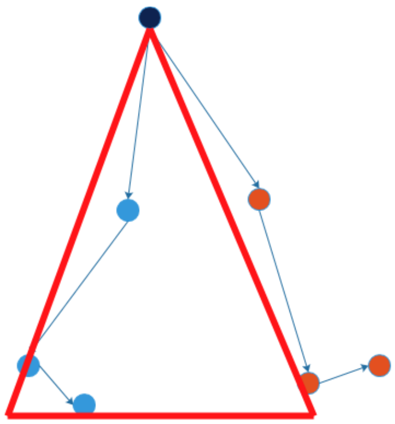

Fig. 3. Triangle Pattern

D. Calories

Calculation of calorie requirements is needed to determine calories that need to be burned efficiently. Calorie burning, especially for medical rehabilitation, requires burning calories properly.

Algorithm 1 Calibration Process

Input: Accelerometer x, y, z, Gyroscope x, y, z
Output: Update Δ during duration
if data arrives **then**
  if this is first data **then**
    $\Delta_{min} = \min(x, y, z)$
    $\Delta_{max} = \max(x, y, z)$
  end if
end if
if Δ_{min} **and** Δ_{max} is not empty **then**
  $\Delta_{\min\_avg} = \sum_n \min(x, y, z)\ /n$
  $\Delta_{\max\_avg} = \sum_n \max(x, y, z)\ /n$
  if $\Delta_{\min\_avg} < \Delta_{min}$ **and** $\Delta_{\max\_avg} < \Delta_{max}$ **then**
    $\Delta_{min} = \Delta_{\min\_avg}$
    $\Delta_{max} = \Delta_{\max\_avg}$
  end if
end if

Algorithm 2 n-Steps Leisurely Walk

Input: Accelerometer x, y, z, Gyroscope x, y, z, Δ_{min}, Δ_{max}, distance
Output: Update *Steps* during duration
if data arrives **then**
  if this is first data **and** $distance = 0$ **then**
    if $\Delta_{min} > (x, y, z) > \Delta_{max}$ **then**
      step++
  else
    $\Delta_{\min} = \sum_n \min(x, y, z)\ /n$
    $\Delta_{\min} = \sum_n \min(x, y, z)\ /n$
    $\Delta_{min} > (x, y, z) > \Delta_{max}$
      step++
  end if
end if

Algorithm 3 Calories Reduction

Input: Steps, duration, weight
Output: Update *Calories* during duration
if data arrives **then**
  MET = Steps/duration
  Calories= $(\text{MET} * 7.8 * (\text{weight} * 2.2))/200 * (\text{duration}/60)$
end if

$$\text{Calories} = (\text{MET} * 7.7 * (\text{weight} * 2.2))/200 * (\text{duration}/60) \quad (2)$$

Medical rehabilitation patients generally cannot carry out too many activities, therefore knowing this can prevent accidents. For calorie calculation as shown in Equation 2 we use Metabolic Equivalent Of Task (MET).

Implementation of MET need three parameters Steps, Duration and Weight, for some problems usually MET needs gender clasification, but in this problem we ignore it. before running the calorie calculation process, it is necessary to calculate footsteps using Algorithm 2. Algorithm 2 will run the footstep calculation process based on the calculation of the threshold specified in the calibration section. After getting the number of steps, the MET calculation can be done by calculating all parameters in Algorithm 3.

III. Result and Discussion

A. Experimental Setup

Before using the footstep monitoring tool, connect the WIFI smartphone with the tool. Tools placed on the thigh then do the monitoring with the application. To detect footsteps, each data has a predefined upper and lower value limits. If the data is less than -20 then there is a marker that the data has reached the lowest point, then the sensor reads the data again. If the data is above 20 and the data marker has read the lowest point, then the number of steps is added 1. After step plus 1, the step multiplied by the average foot width when stepping (0.7m) then obtained the distance.

Ethical Clearance, each test is accompanied by a therapist. All activities have been ensured safe to do. The movements performed are determined by the therapist including the number of calories that need to be burned.

B. Design Testing

In design testing, the testing doing by five person to activity leisurely walk, as shown in Table 1 the distance has been determined in advance so that the ground truth can be known the number of footsteps taken.

TABLE I. Table Activity

Activity	Footsteps	Distance
Leisurely Walk	4 Step	2,4 Meter
	8 Step	4,8 Meter
	10 Step	6 Meter
	15 Step	9 Meter
	20 Step	14 Meter

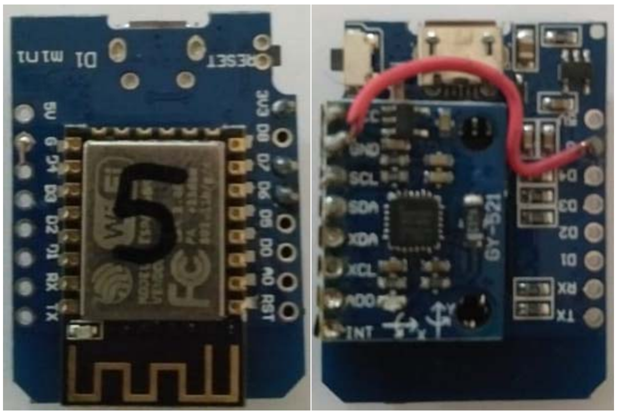

Fig. 4. Device Used

In the research, Wemos D1 Mini was used which was connected directly to the MPU6050, and a 3.3 volt battery as shown in Figure 4.

C. Result

From the walking activity conducted by the testers as much as 4, 8, 10 steps as shown in Figure 5 - 8, obtained data from the sensor, convert the data into the sine wave to know the movement of the step to generate how many waves. Wave results are determined by a threshold above and threshold below to detect footsteps that will be displayed on Android applications. Table 2 shows the differences in calculation results performed by tools based on the ground truth in Table 1. In addition, testing was also carried out with equipment that had been circulating in the market, in this study a comparison was carried out using Mi Band 2. After the result of threshold comparison then detection step is shown .

TABLE II. Result and Difference in Counting

Device	Manual	Difference
4	4	0
8	8	0
10	10	0
14	15	1
18	20	2

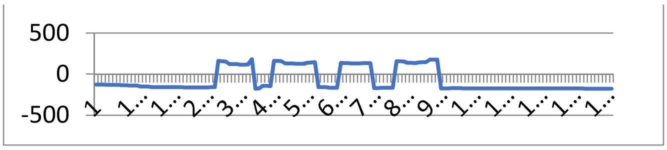

Fig. 5. 4 Steps Leisurely Walk

TABLE III. Difference Counting with Market Based

Steps	Test 1		Test 2		Avg		Diff.
	Mi Band 2	Our	Mi Band 2	Our	Mi Band 2	Our	
5	6	5	4	5	5	5	0
10	17	10	19	10	18	10	8
15	34	14	25	15	29,5	14,5	15
20	43	20	35	19	39	19,5	19,5
25	50	23	56	25	53	24	29

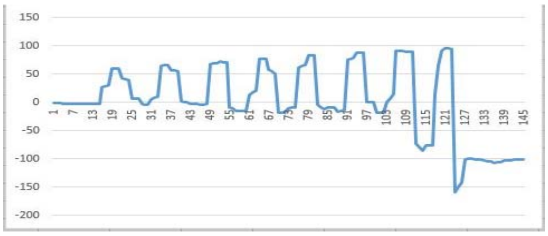

Fig. 6. 8 Steps Leisurely Walk

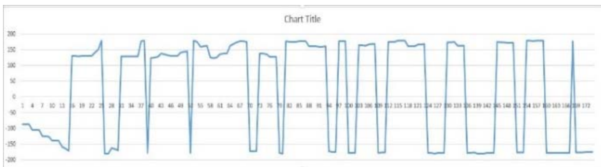

Fig. 7. 10 Steps Leisurely Walk

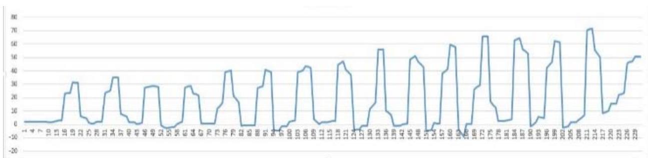

Fig. 8. 15 Steps Leisurely Walk

IV. Conclussion

From the results of tests conducted in detecting footsteps as much as 57 times, obtained an error value of 3.65% means the system is able to detect foot activity with good enough. Monitoring results depend on the laying of the sensor. Use of the tool is very useful to minimize injuries that can occur. The average results obtained for the activity runs smoothly, the movement of each footstep is very regular.

References

[1] I. Gringauz *et al.*, "Risk of falling among hospitalized patients with high modified Morse scores could be further Stratified," *BMC Health Serv. Res.*, vol. 17, p. 721, Nov. 2017.

[2] D. J. Clark, "Automaticity of walking: functional significance, mechanisms, measurement and rehabilitation strategies," *Front. Hum. Neurosci.*, vol. 9, p. 246, May 2015.

[3] Y.-H. Pua, R. A. Clark, and P.-H. Ong, "Evaluation of the Wii Balance Board for Walking Aids Prediction: Proof-of-Concept Study in Total Knee Arthroplasty," *PLoS One*, vol. 10, no. 1, p. e0117124, Jan. 2015.

[4] M. H. C. Bleijlevens, J. P. M. Diederiks, M. R. C. Hendriks, J. C. M. van Haastregt, H. F. J. M. Crebolder, and J. T. van Eijk, "Relationship between location and activity in injurious falls: an exploratory study," *BMC Geriatr.*, vol. 10, p. 40, Jun. 2010.

[5] V. Viegas, J. M. Dias Pereira, O. Postolache, and P. S. Girão, "Monitoring Walker Assistive Devices: A Novel Approach Based on Load Cells and Optical Distance Measurements ," *Sensors (Basel).*, vol. 18, no. 2, p. 540, Feb. 2018.

[6] J. A. Stevens, K. Thomas, L. Teh, and A. I. Greenspan, "Unintentional Fall Injuries Associated with Walkers and Canes in Older Adults Treated in U.S. Emergency Departments," *J. Am. Geriatr. Soc.*, vol. 57, no. 8, pp. 1464–1469, Jul. 2009.

[7] H. Bateni and B. E. Maki, "Assistive devices for balance and mobility: Benefits, demands, and adverse consequences," *Arch. Phys. Med. Rehabil.*, vol. 86, no. 1, pp. 134–145, Jan. 2005.

[8] T. Z. Sudbury, "Development of biomechanical analysis techniques for fatigue of transtibial prosthetic socket and pylon interactions," 2014.

[9] M. Alwan, A. Ledoux, G. Wasson, P. Sheth, and C. Huang, "Basic walker-assisted gait characteristics derived from forces and moments exerted on the walker's handles: results on normal subjects.," *Med. Eng. Phys.*, vol. 29, no. 3, pp. 380–389, Apr. 2007.

[10] A. Muro-de-la-Herran, B. Garcia-Zapirain, and A. Mendez-Zorrilla, "Gait analysis methods: an overview of wearable and non-wearable systems, highlighting clinical applications.," *Sensors (Basel).*, vol. 14, no. 2, pp. 3362–3394, Feb. 2014.

[11] E. Sardini, M. Serpelloni, and M. Lancini, "Wireless Instrumented Crutches for Force and Movement Measurements for Gait Monitoring," *IEEE Trans. Instrum. Meas.*, vol. 64, no. 12, pp. 3369–3379, 2015.

[12] D. D. Ely and G. L. Smidt, "Effect of cane on variables of gait for patients with hip disorders.," *Phys. Ther.*, vol. 57, no. 5, pp. 507–512, May 1977.

[13] L. C. Masse *et al.*, "Accelerometer data reduction: a comparison of four reduction algorithms on select outcome variables.," *Med. Sci. Sports Exerc.*, vol. 37, no. 11 Suppl, pp. S544-54, Nov. 2005.

[14] I.-M. Lee and E. J. Shiroma, "Using accelerometers to measure physical activity in large-scale epidemiological studies: issues and challenges.," *Br. J. Sports Med.*, vol. 48, no. 3, pp. 197–201, Feb. 2014.

[15] S. K. Keadle, E. J. Shiroma, P. S. Freedson, and I.-M. Lee, "Impact of accelerometer data processing decisions on the sample size, wear time and physical activity level of a large cohort study.," *BMC Public Health*, vol. 14, p. 1210, Nov. 2014.

[16] CNN, "Turunkan Berat Badan dengan Berjalan Kaki," *2017*, 2017. [Online]. Available: https://www.cnnindonesia.com/gaya-hidup/20160818115814-255-152171/turunkan-berat-badan-dengan-berjalan-kaki/.

[17] A. T. S. Wahyu Andhyka Kusuma, Zamah Sari, "Sensor Fusion Accelerometer dan Gyroscope untuk Pengukuran Perubahan Kinematik Pergelangan Kaki," *Kinetik*, vol. 1, no. 1, pp. 17–22, 2016.